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Current and potential capabilities of biomass for green energy in Iran

Yahya Hamzeh[a], Alireza Ashori[b,*], Babak Mirzaei[a], Ali Abdulkhani[a], Masoumeh Molaei[a]

[a] Department of Wood and Paper Science and Technology, Faculty of Natural Resources, University of Tehran, Karaj, Iran
[b] Department of Chemical Technologies, Iranian Research Organization for Science and Technology (IROST), Tehran, Iran

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ABSTRACT

In this work, biomass-derived energy has been highlighted and biomass has been divided into three main categories: agricultural residues, animal waste, and municipal solid waste. Energy is essential for the economic and social development and improved quality of life in Iran as in other countries. Much of the world's energy requirement, however, is currently produced from fossil fuels that could not be sustained if technology were to remain stagnant and if overall quantities were to increase substantially. The process of controlling atmospheric emissions of greenhouse and other gases and substances should increasingly be based on efficiency in energy production, transmission, distribution and consumption in the country. The need for transition to sustainable energy resources has been recognized in Iran. To reduce and utilize the waste produced from these resources and be benefited from green fuels, an assessment was carried out to provide an overview on green energy potentials in Iran. The annual biomass potentials of Iran in terms of agricultural, animal and municipal wastes are 8.78×10^6, 7.7×10^6 and 3×10^6 tonnes, respectively. In addition, poplar planting and microalgae can play an important role in the future scenario of wood supply and energy recovery in Iran.

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1. Introduction

Iran is a developing country located in the southern part of Caspian Sea. It has an area of 1,648,195 km^2 and a population of about 73 million. Iran is ranked as one of the top countries with many renewable and non-renewable natural resources. Iran's oil reserves are the second largest in the Middle East, after Saudi Arabia. In addition, Iran holds the second largest natural gas reserves in the world [1]. Energy is essential to the economic and social development and improved quality of life in Iran as in other countries. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain stagnant and if overall quantities were to increase substantially [2]. Fig. 1 shows the share of total primary energy consumption in the world and Iran in 2008 [3]. The energy consumption pattern of the world indicates that the shares of oil and coal in the world's total energy consumption are 33.1% and 27%, respectively, while in Iran the share of natural gas and oil from the total energy consumption are 54.4% and 44.1%, respectively. The energy consumption pattern also shows that 10% of the total energy in the world is derived from biomass while 90% is provided by fossil and conventional energy, resulting in the overall natural calamities and worldwide competition for the energy resources.

Coal, oil, and natural gas are all fossil fuels. The application of fossil fuels as energy sources is unsustainable due to the depletion of the limited energy resources and also the emission of greenhouse gases into the environment. Greenhouse gases contribute to

* Corresponding author. Tel.: +98 228 2276637; fax: +98 228 2276265.
E-mail address: ashori@irost.org (A. Ashori).

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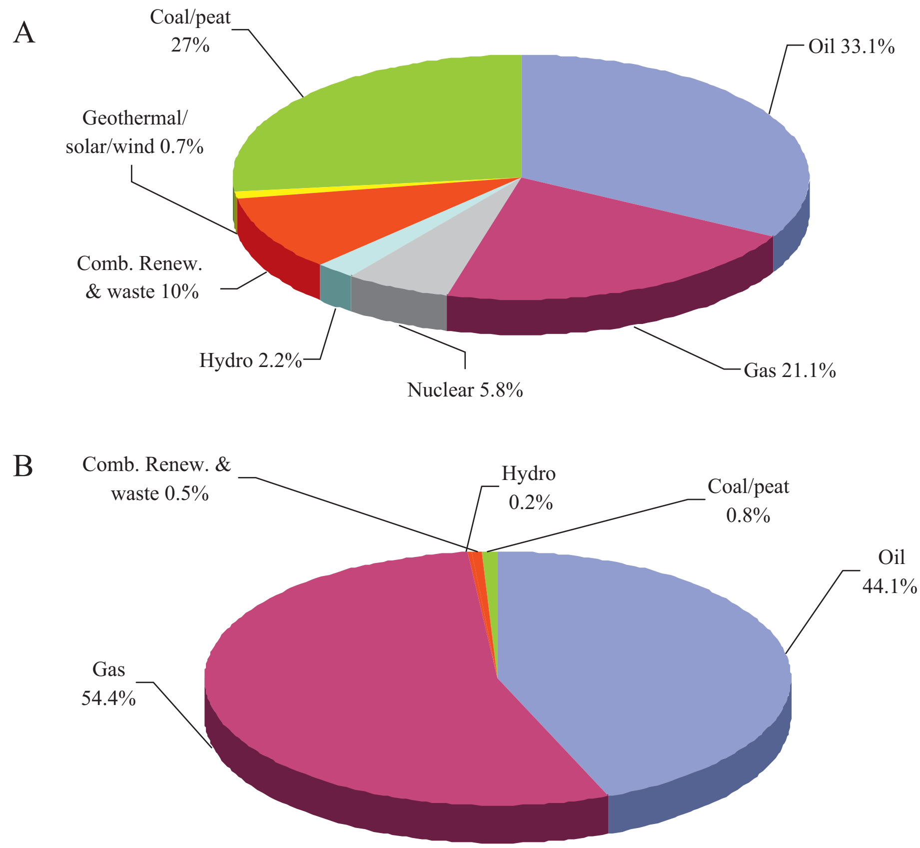

Fig. 1. Energy consumption pattern for the world (A) and in Iran (B) in 2008 [1].

global warming and also have other impacts on the environment and human life. Recently, the potential threat of global climate change has increased, and fossil fuel usage has had the highest contribution to greenhouse gas emissions [1]. For instance, in 2009, the fossil fuels associated CO_2 emission was about 527×10^6 tonnes in Iran. Fig. 2 shows the trend of CO_2 emissions in Iran during the last ten years [4]. In addition, because of the adsorption of one-third of the CO_2 emitted each year into the oceans, the water pH is turning gradually to more acidic, which will adversely affect marine ecosystem biodiversity [5]. Regarding the mentioned problems, therefore, alternative sources and methods of energy production should be taken into consideration. Biomass-based energy has certain important advantages compared to fossil fuels, such as reducing the greenhouse gas emissions, increasing national energy security, increasing rural development, and sustainable fuel supply for the future [6,7].

The need for transition to sustainable energy resources has been recognized in Iran. Renewable Energy Organization of Iran has established various research programs for development of bioenergy (green energy) production from biomass. However, there is not a comprehensive report on potentially available biomass resources in Iran. The main objective of this work is to estimate the potentially available biomass resources in Iran and their contribution for biogas, bio-fuel and power generation. It is important to note that this study has been carried out on the basis of the available data and our analysis on the main biomass resources of Iran including residues from agricultural and forestry, industrial wastes and municipal solid wastes.

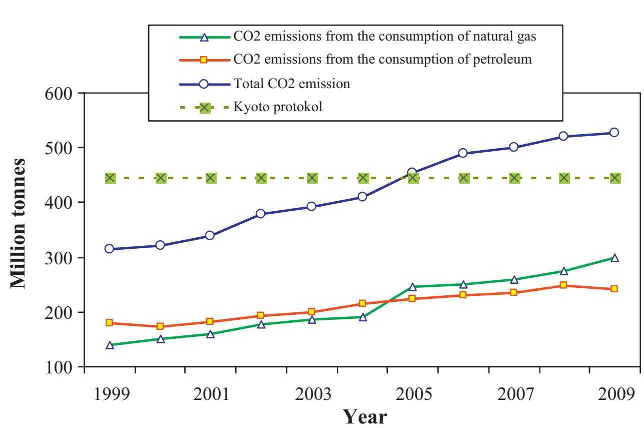

Fig. 2. Trend of CO_2 emissions in Iran [4].

2. Agricultural residues

Iran is a developing country whose agricultural status plays an important role in the rural economy and also macroeconomic performance of the country. Due to the diversity in climatic situation in Iran, different crops can be cultivated in different regions. A third of Iran's total land area can be utilized to produce crops if sufficient water is provided. However, only 12% of the total land area is utilized for growing various crops. The most cultivated crops in Iran are cereal, sugar cane, rice, date, barley, potato, corn, sugar beet, grape, and canola. The total production of wheat, corn, rice and barley rapidly increased in the previous decade. This increase is attributed to a combination of higher yields and seeded area [1].

Almost the majority of agricultural wastes were disposed due to low capacity of the converting industrial plants. There is only one factory located in the southern part of Iran which uses the bagasse as a raw material, and some studies on the utilization of

Table 1
Potential bioethanol from agricultural residues in Iran in 2008 [1,4,9].

Crop	Production (10^6 tonnes)	Residues (%)	Residues (10^6 tonnes)	Ethanol yield of residues ($L\,kg^{-1}$)	Total bioethanol (GL)
Wheat	13.48	57	7.62	0.29	2.21
Sugarcane	2.8	100	2.8	0.28	0.78
Rice	2.25	58	1.31	0.28	0.37
Barley	3.45	55	1.88	0.31	0.58
Corn	1.64	50	0.82	0.29	0.24
Potato	4.11	30	1.23	0.11	0.13
Date	1.0	40	0.4	0.36	0.14
Sugar beet	2.02	100	2.02	0.3	0.61
Grape	1.7	30	0.51	0.28	0.14
Apple	2.7	30	0.81	0.28	0.23
Total	35.15	–	19.4	–	5.69

this feedstock as lignocellulosic raw materials for pulp and paper and bio-energy production are ongoing. Except for some areas in the central Iran, agricultural residues make a reliable and evenly distributed source for energy production in the entire land. Table 1 shows the energy potential of agricultural residues in Iran in 2008 [1,8,9]. As it can be seen, 19.4×10^6 tonnes of residues (equivalent to 8.78×10^6 tonnes combustible feedstock) are annually generated which are mostly disposed or burned. Primary energy demand in Iran is projected to increase at an average annual rate of 2.6% in 2003–2030 period, down from around 5% over the past decade. This is based on the assumption of continued removal of energy subsidies, which is now equivalent to a staggering 10% of Gross Domestic Product (GDP) [1]. Iran's total primary energy consumption in 2009 was 204.8×10^6 tonnes [3]. Considering this increasing rate, the quest for alternative energy sources should not be neglected. One of the best examples is producing bioethanol from crop residuals. If the calorific value of each cum bioethanol is considered 0.51 tonne, the total energy potential of yielded bioethanol will be equivalent to 11.16×10^6 tonnes. Indicating the higher energy efficiency of bioethanol compared to feedstock, this sum can compensate the 2008–2009 increase of energy consumption in Iran.

3. Animal wastes

Rapidly growing population in Iran hastens the development of industries that are integrated in nourishment supply chain. Animal husbandry is one of such industries. Since, animal husbandry is highly developed in Iran; a considerable amount of animal dung is produced annually. Animal dung is mainly used as natural fertilizer in farms. Energy recovery from substantial animal dung is not only important from the environmental protection point of view, but also for economical reasons. Table 2 gives the bioenergy potential of animal wastes in Iran in 2008 [9,10]. Total energy potential of animal wastes in Iran was estimated to be 7.7×10^6 tonnes in 2008. Since livestock waste is a rich source of organic matter, it can best be utilized in biogas reactors.

Table 2
Total bioenergy potential of animal waste in Iran in 2008 [9,10].

Kind of animal	Number of animals[a]	Coefficient of conversion[b]	Total energy potential[c]
Sheep and goats	78,026	0.048	3745
Donkey, horse, mule and camel	1823	0.235	428
Poultry	481,000	0.003	1443
Cattle	8548	0.245	2094
Total	–	–	7710

[a] Thousand head.
[b] 10^3 tonnes per thousand animals.
[c] 10^3 tonnes.

4. Municipal solid wastes

The national average of municipal solid waste (MSW) in Iran is at 0.2–0.5 kg per person per day, but in the capital city of Tehran, this figure has escalated to 0.88 kg per person per day [11]. This value is estimated to be 2.7, 0.5 and 0.2 kg in the USA, Pakistan and some African countries, respectively [16]. For any given city, this value mainly depends on consumption pattern and the income of the city inhabitants. MSW is a great source of pollution and carrier of many infectious diseases in and around every city. Hence, appropriate management of MSW is of utmost importance. Currently, landfilling is the main waste management strategy in Iran and the rest of MSW is composted and recycled. However, due to the substantial growth in energy demands in Iran this source can be regarded as a smart option for energy recovery. In the waste management hierarchy, waste to energy has been considered as a mode for the recovery of resources that must be considered before the ultimate disposal of the final inert materials [12]. Renewable Energy Organization of Iran, which is responsible for developing renewable energy supply in the land, currently conducts following projects to recover MSW energy; firstly, conducting a feasibility study for cities having population over 250,000 for locating and constructing a 10 MW station, and secondly, manufacturing Iran's first biogas plant for power generation in Saveh city (62 miles southwest of Tehran) with the capacity of 460 kW [13]. Table 3 shows the average composition of components in MSW generated in Tehran [14]. Typical composition of MSW of developing countries can be observed in this table. Approximately 15×10^6 tonnes are annually generated as MSW in Iran [15]. With regard to previous works on the calorific value of MSW of developing countries [12,16], the energy potential of Iran's MSW is estimated to be about 3×10^6 tonnes annually. This sum indicates a potential alternative energy source that can better be utilized in household sector by developing biogas plants. High organic content of the waste has made it more suitable for this target.

Table 3
Composition of materials in Tehran (Iran) municipal solid waste [14].

Source	Amount in municipal solid waste	
	Weight (10^3 tonnes)	Percentage
Stale bread	35.5	42.1
Paper and paperboard	18.6	22.1
Miscellaneous inorganic	11.1	13.2
Plastics	9.4	11.2
Metals	7.6	9.0
Glass	1.4	1.7
Textiles	0.6	0.7
Total	84.2	100

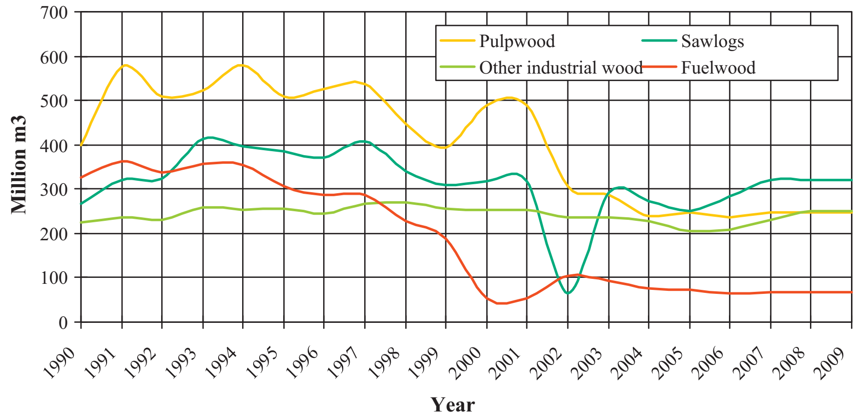

Fig. 3. Wood raw material production from natural forests in Iran [9].

5. Forest resources

Total forest area of Iran is $14{,}319 \times 10^3$ ha of which the share of closed, semi-closed and open forests are 1780, 3468 and 8101×10^3 ha, respectively [9]. These forests occupy about 7% of the country's land area. Iran's important indigenous forest species are hardwoods. They are maple, alder, box tree, beech, oak, blue beech and Iron wood. To a large extent, beech (*Fagus orientalis*) is the most conventionally valuable source of wood in Iran's forests, which is located in Hyrcanian forests in the northern part of Iran and southwestern of coastal region of Caspian Sea. Due to suitable temperature and ample rainfall, Hyrcanian forests, located between Alborz Mountains and Caspian Sea, are the most productive forest lands in Iran. Forest destruction in the country is mainly due to illegal cutting, fires, and uncontrolled grazing, especially for goats. However, because of sharp harvesting the severe protecting programs has been established to preserve the remaining forests, but still illegal cuttings amount to a considerable percentage of forest destruction. Apart from their economical value, they are mainly considered as rich ecological forests with wealthy biodiversity. Also some forest lands are located in western and southern parts of Iran, but they are not considered as valuable wood production sources. Fig. 3 shows wood raw material production in Iran. Pulpwood and fuelwood production exhibit declining trends. Typically, Iran's forest species can yield more value-added products if they are utilized in industrial and constructional applications. Hence, indigenous sawlogs are currently in high inland demand. Moreover, poplar plantations have been implemented by both governmental bodies and private sector to improve wood production potentials in Iran. The plantation area for a period of ten years (1994–2004) in Iran was 425×10^3 ha and the annual wood production potential of planted area in 2004 was 2.3×10^6 m^3 [17]. This amount does not seem to be adequate to meet local needs, and drastic measures should be taken, which would demand changes in relevant policies, to remove pressures on pale arctic forests and to supply sufficient raw material. Poplar is a fast-growing species whose annual bioethanol yield is 3700–6000 L ha^{-1}, and can save greenhouse gas by 51–100% versus petroleum [18]. In terms of inland wood production status, poplar planting is an appropriate option to provide a reliable wood supply and energy resource.

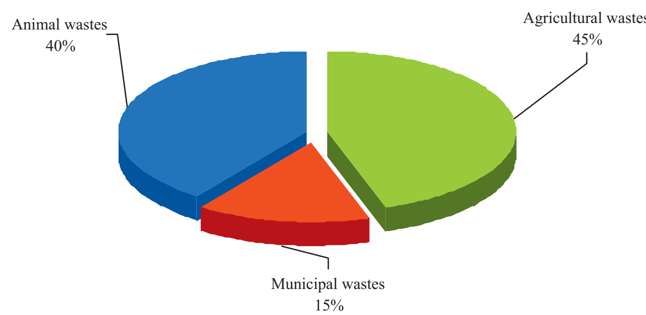

Fig. 4. Share of potential energy of biomass waste in Iran [3].

Fig. 4 shows the share of potential biomass waste energy in Iran. Potential energy values of agricultural, animal and municipal wastes are 8.78×10^6, 7.7×10^6 and $3 \times 10^6 \times 10^6$ tonnes, respectively. The total sum will be equivalent to 19.48×10^6 tonnes annually.

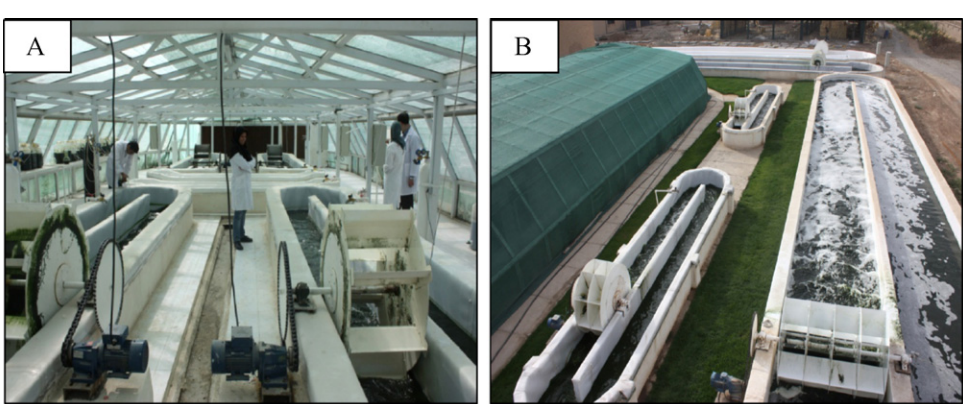

Fig. 5. (A) Indoor and (B) outdoor raceway ponds agitated by paddle wheels for production of microalgae in Iran [20].

6. New generation of biomass

Among the renewable energy sources, microalgae are new generation of biomass materials. The main alternative to fossil fuel is biodiesel. The production of biodiesel has received much attention worldwide and was one of the first alternative fuels to become known to the public [19]. Microalgae are unicellular photosynthetic microorganisms, living in saline or fresh water environments that convert sunlight, water and carbon dioxide to algal biomass. Microalgae can provide several different types of renewable biofuels. These include methane produced by anaerobic digestion of the algal biomass, biodiesel derived from microalgal oil, and photobiologically produced biohydrogen. In recent years, usage of microalgae as biodiesel feedstock has attracted great attention. The idea of using microalgae as a source of biodiesel is not new. It was first proposed in the 1950s and, since the 1970s, several publicly funded research programs in different countries (such as USA, Australia, and Japan) have investigated microalgae cultivation for producing renewable liquid fuels. Based on Moazami and co-workers' report [20], microalgae are promising source of biomass for producing biofuel in Iran. Fig. 5 shows indoor (A) and outdoor (B) raceway ponds agitated by paddle wheels for large scale production of microalgae at IROST, Iran.

7. Conclusions

Iran is one of the top countries in many natural resources such as crude oil, natural gas and minerals. However, the utilization of these natural resources is limited. Iran's rich fossil fuel reserves have brought about unbridled consumption of these fuels. Consequently, Iran ranked 10th worldwide in CO_2 emission in 2009, and recently has passed Kyoto protocol limitation. On the other hand, Iran enjoys rich renewable natural resources which can provide supplementary energy resources for partially substituting gasoline, diesel and natural gas consumption. Furthermore, with regard to fast growing population of Iran and substantial waste production, waste management policy in different sectors demand novel solutions. One of the best options to reduce waste and meanwhile produce green energy is energy recovery from bio-based wastes. In this regard, this study has been conducted to evaluate bioenergy potentials in Iran from biomass wastes, and the following conclusions are drawn:

1. Agricultural feedstock is the principle contributor to the biomass waste produced in Iran. Approximately, 19.4×10^6 tonnes of residues are produced from main harvests in Iran. With regard to Iran's considerable gasoline import, this source also can be considered as a generous bioethanol production source.
2. The other waste which can be effectively utilized as an energy source is animal dung. This source after agricultural wastes has the highest share in potential energy production from biomass wastes in Iran.
3. MSW also has an important share in the annual biomass waste that is generated in Iran. The MSW produced in Iran is mainly composed of organic matters, and this makes it more suitable for energy recovery. However, compared to lignocellulosic or animal wastes the calorific value of MSW is still low.
4. Since forests in Iran are mainly protected, the share of forest cleanings and wood industry residues are negligible in potential bioenergy utilization. However, poplar planting can play an important role in the future scenario of wood supply and energy recovery.
5. Microalgae are new generation of biomass which can provide several different types of renewable biofuels in Iran.

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